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EVALUATION OF SELECTED SENSORS FOR AUTOMATED TAC
WEATHER OBSERVATIONS(U) AIR FORCE GEOPHYSICS LAB

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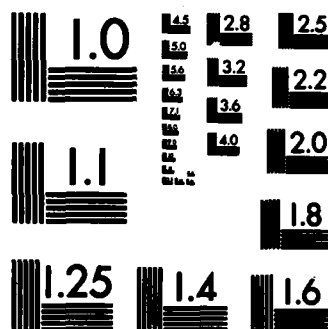
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Figure 1

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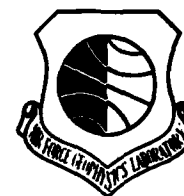
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Evaluation of Selected Sensors for Automated Tactical Weather Observations

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8 July 1982

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Under the current effort the following actions were completed: (1) translators were designed and built for AWS wind and temperature/dew point measuring sets in order to provide for automated operation; (2) intercomparison testing of a number of precipitation gages was performed; (3) a hand held laser rangefinder was evaluated for use as a cloud height measuring device; (4) a prototype tactical visibility meter (TVM) was designed, fabricated, and tested; and (5) the development of a preproduction version of the tactical visibility meter was initiated. Test results are presented.

Future plans have been severely curtailed due to a change in manpower. Only the development of the preproduction TVM will be completed.

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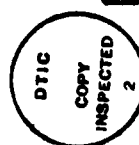
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Summary

A program has been initiated at AFGL to develop an automated tactical meteorological observing station for bare-base airfield operations. A survey of meteorological sensors, both government and commercial, was conducted and suitable sensors were identified. There are no suitable visibility or cloud height sensors presently available for this program. In the current effort, a prototype tactical visibility meter (TVM) was built and tested. Development of an engineering model TVM was initiated. Also a select number of candidate sensors were field testing. Test results are presented.

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Preface

This report by the Air Force Geophysics Laboratory (LYR) is intended to acquaint readers within the Air Force organization, of the direction and considerations contemplated in the selection of meteorological sensors for use in an automated tactical weather station. No reference shall be made to the AFGL in advertising or sales promotion concerning any proprietary product discussed in this report which would imply endorsement of that product by this organization. The fact that specific products may not have been mentioned should not be constructed as a reflection upon their quality.

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Evaluation of Selected Sensors for Automated Tactical Weather Observations

1. INTRODUCTION

The Air Force Geophysics Laboratory (AFGL) has undertaken a program to provide Air Weather Service (AWS) with a modern automated system for the acquisition and processing of meteorological data in a tactical bare-base environment. This Automated Tactical Meteorological Observing System (ATMOS) will provide accurate and timely information on winds, pressure, temperature/dew point, precipitation, visibility and cloud height.

In the first phase of the program, an evaluation¹ was made of meteorological sensors in the AF inventory to determine their suitability for use in an automated weather station. Concurrently, a survey of state-of-the-art meteorological instruments and measuring techniques was conducted.

The results of this evaluation showed that none of the AWS sensors are directly applicable to such a system. However, the AN/TMQ-15, Tactical Wind Set, and the AN/TMQ-20, Tactical Temperature/Dew Point Measuring Set, appeared to have sufficient potential that it would be worthwhile to adapt them for automated operation. The survey also revealed that there were commercially available sensors that can meet the requirements of ATMOS in all the measurement categories, with the

(Received for publication 6 July 1982)

1. Moroz, E. Y., and Brousaides, F. J. (1980) Survey of Sensors for Automated Tactical Weather Observations, AFGL-TR-80-0195, ADA094121.

exception of visibility and cloud height. None of the available visibility meters can fulfill the requirements for tactical operations. It was felt that the laser range-finder technique was the best technique available for determining cloud height in tactical situations and there have been a number of attempts to develop an instrument using this technique; to date, all have been unsuccessful. However, the technology in the visibility and cloud height areas is adequate for the development of suitable sensors.

Various tasks performed during the current phase of the program are described in this report. These tasks include: (1) the modification of the AN/TMQ-15, Wind Measuring Set, and the AN/TMQ-20, Temperature/Dew Point Measuring Set, for automated operation; (2) the development and test of a tactical visibility meter (TVM); (3) intercomparison testing of a number of precipitation gages; and (4) evaluation and test of the hand-held AN/GVS-5 Laser Rangefinder as a cloud height measuring set.

There are no pressure gages in the AWS inventory suitable for ATMOS operation; no commercial gages were obtained for evaluation in the current effort. It is anticipated that most of the commercially available gages could be incorporated into ATMOS without any difficulty.

2. WINDS

The assessment¹ of the AN/TMQ-15, Tactical Wind Speed and Direction Measuring Set, revealed the following advantages:

- (1) It was capable of providing adequate wind information for tactical bare-base operations,
- (2) It performed well in the field and,
- (3) A large number of these sets are in the AWS inventory.

The major disadvantage was that its output was not suitable for direct interfacing with an automated weather station. Because of the obvious cost and logistics advantages of using the AN/TMQ-15 for bare-base operations, it was decided to obtain a translator for the automated operations of the wind set.

A brassboard model of the translator was designed and built by ERTEC, Inc., Newton, Massachusetts. In this system, the original sensors were kept intact, with the exception that only one fixed coil (north) was used to determine wind direction. The translator eliminates the need for both the Wind Data Converter and the Wind Speed and Direction Indicator components of the basic set. A block diagram of the translator is shown in Figure 1. The translator has three outputs:

- (1) An eight-bit databus processor with an output adequate for determining wind direction to a resolution of $\pm 2^\circ$ and wind speeds to 100 knots,

- (2) An analog output for recording purposes, and,
- (3) LED displays of wind direction and wind speed, which are updated every 5 seconds. The number of counts between north pulses can also be displayed, if desired.

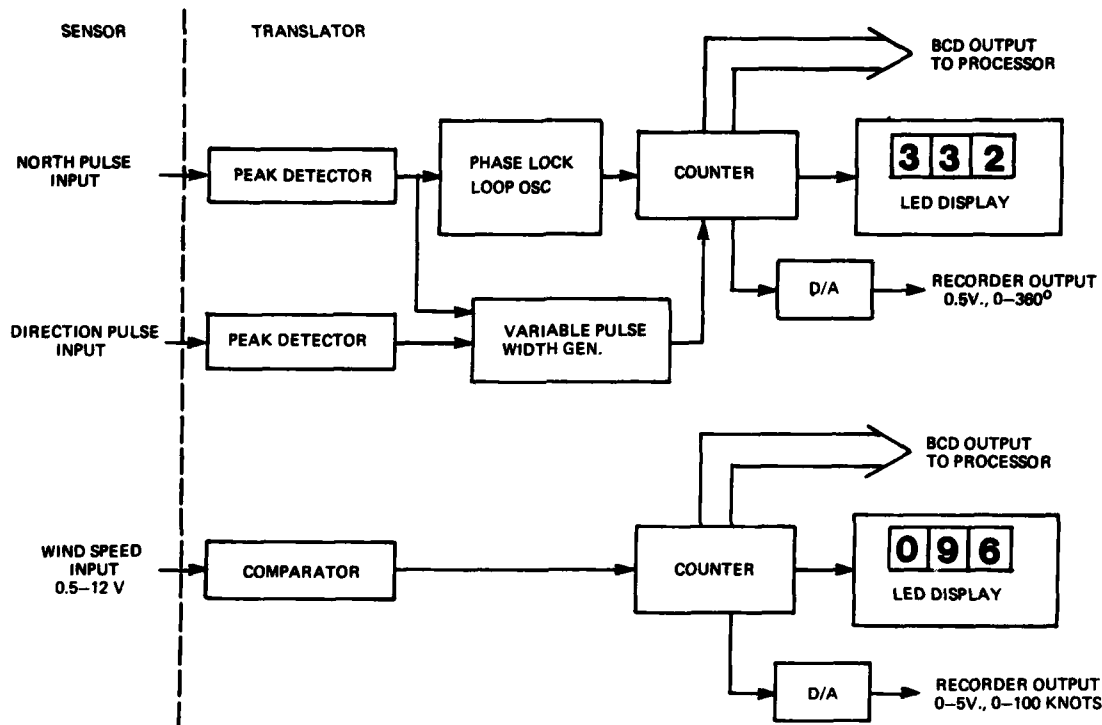


Figure 1. Block Diagram of Translator for Automating Operation of AN/TMQ-15, Tactical Wind Measuring Set

During initial bench tests, the translator's operation was optimized and its calibration verified. The equipment was then set up at the weather test site on Reservoir Hill, Hanscom AFB, Massachusetts and tested for three months. The set operated without any failures and maintained its calibration throughout the period. The brassboard model was considered a success.

The contractor, Ertec, Inc., was tasked to provide an engineering model of the translator. Only preliminary testing of the preproduction model shown in Figure 2, have been performed. It appeared to have provided a satisfactory interface between the AN/TMQ-15 sensors and any automated weather station processor.

It should be noted that the translator was not capable of resolving the wind direction ambiguity that occurred during a "North" reading (360° vs 0°). The processing sophistication capability required to resolve this ambiguity should be part of the ATMOS main processor.

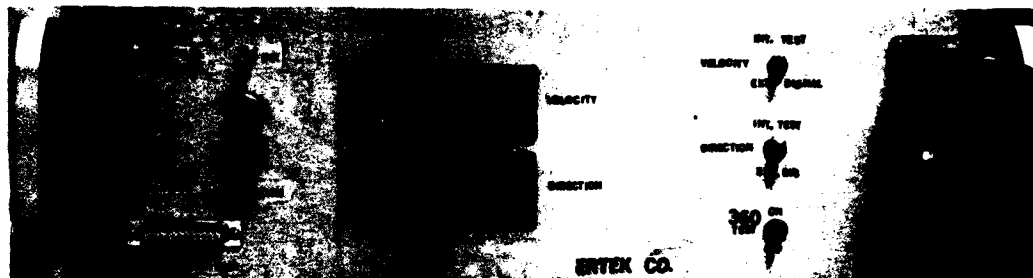


Figure 2. Engineering Model of AN/TMQ-15 Translator

3. PRECIPITATION

The assessment¹ of precipitation measurement devices showed that there are no gages within AWS suitable for automated operation. It was further shown that commercially available tipping bucket and weighing bucket gages were adequate for ATMOS operation, with tipping bucket gages having an advantage because of their ruggedness and reliability.

Two tipping bucket gages were obtained for evaluation. One, a Belfort Model 5-4054A, was selected because it was in wide use and was built to National Weather Service (NWS) specifications. The other gage, a Weather Measure Model P511-E, was chosen because it has received considerable attention by other government agencies for use in automated weather systems. Both gages were calibrated in increments of 0.01 in (0.25 mm) precipitation. Manufacturer's specifications for the two gages are given in Appendix A. A Belfort Model No. 5915 weighing bucket gages was also purchased for comparison with the tipping bucket gages.

Calibration and testing of the gages were performed at the AFGL Weather Test Facility (WTF), where there were facilities for automatically recording the data, and there were a number of other gages available for comparison testing. Precipitation gages permanently located at the site included a sensitive 0.005 in (0.13 mm) Belfort tipping bucket gage (shown in Figure 3) and two recording Belfort Universal rain gages. The three test gages were set out 6 m apart in an open area 100 m from the permanently installed gages (see Figure 4).

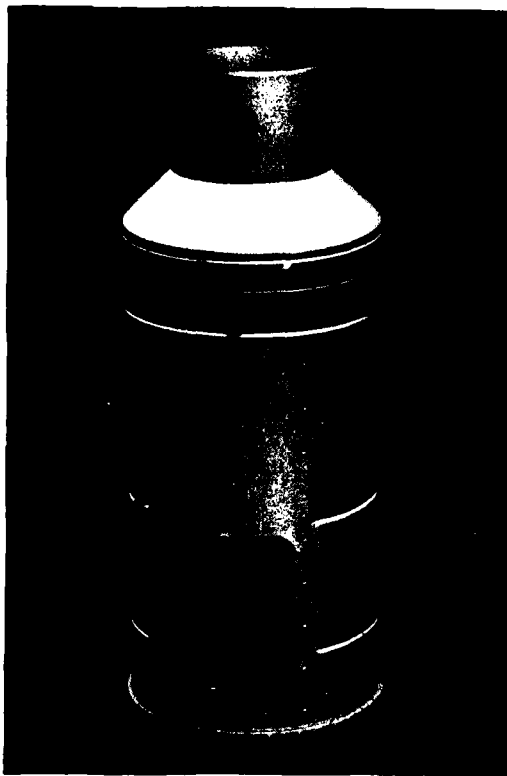


Figure 3. Belfort 0.005 in
Tipping Bucket Precipitation
Gage

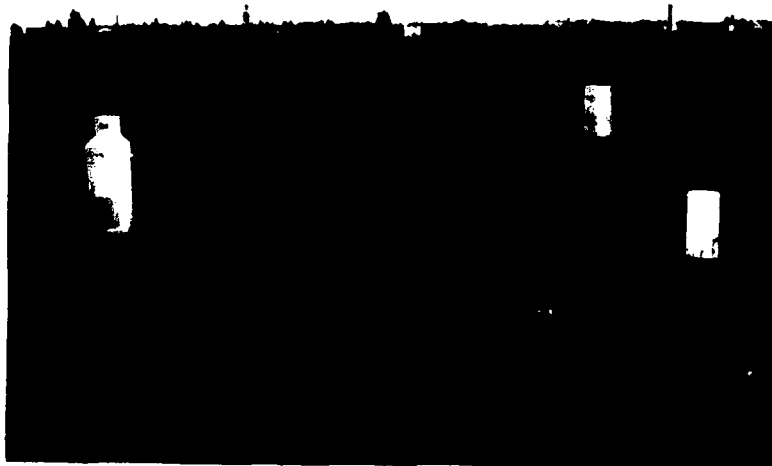


Figure 4. Precipitation Gage Installation; Left to Right,
Belfort Weighing Gage, Belfort 0.01 in Tipping Bucket
Gage and Weather Measuring 0.01 in Tipping Bucket Gage

3.1 Calibration

The weighing bucket and the three tipping bucket gages were calibrated in the field. The weighing bucket was calibrated by putting an amount of water in it, equivalent to six inches of rain and recording the output voltage (Table 1). The gage's linearity was checked by emptying the contents of a beaker containing 250 ml of water into the gages several times. The corresponding changes in the gage's output voltage were recorded (Table 1). The gage was reasonably linear through its range (see Figure 5).

Table 1. Calibration of Belfort Weighing Bucket Precipitation Gage

Empty Bucket:	0.0 V	
Bucket with six inches of water:	4.1516 V	
Calibration:	(voltage output) \times 1.445 = precipitation amount (inches)	
<u>Linearity Check</u>		
Case Number *	Calculated Water Amount (Inches)	
	Change in Gage Output (Δ Volts)	
1.	0.304	0.208
2.	0.6070	0.207
3.	0.911	0.210
4.	1.214	0.203
5.	1.518	0.215
6.	1.821	0.210
7.	2.125	0.212
8.	2.428	0.215
9.	2.732	0.213
10.	3.035	0.215
11.	3.339	0.205
12.	3.642	0.210
13.	3.946	0.222
14.	4.249	0.198
15.	4.553	0.210
16.	4.856	0.222
17.	5.160	0.208
18.	5.463	0.205
19.	5.767	0.200
20.	6.070	0.215

* In each case a beaker of 250 milliliters of water was poured into the gage.

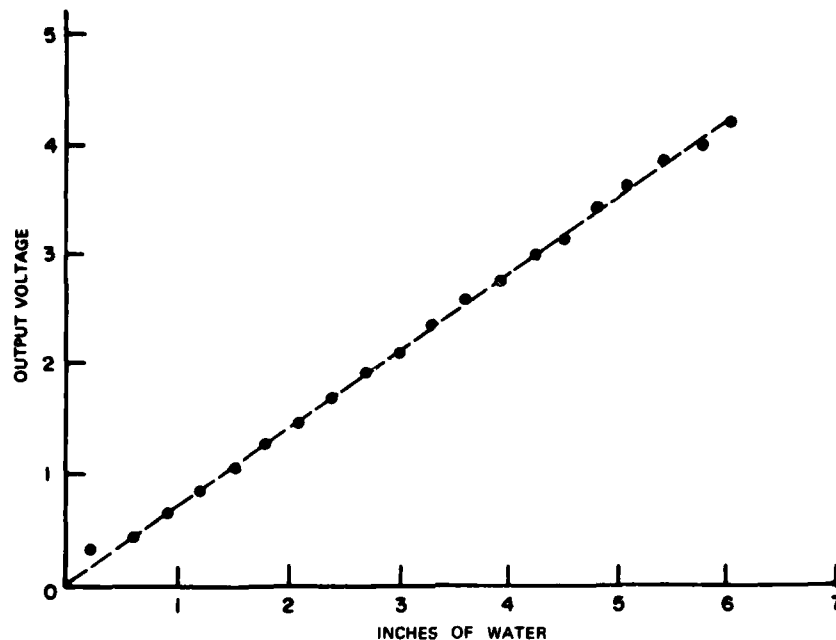


Figure 5. Graph Indicating Linearity of Belfort Weighing Bucket Precipitation Gage

Initially, the tipping bucket gages were calibrated using a similar technique. However, when discrepancies showed up in the test data between the 0.005 in tipping bucket gage and the other gages, the tipping bucket gages were recalibrated. A more precise calibration method was devised using a water container and plastic siphon hoses (1.5 mm ID) to obtain a controlled rate of water flow. The rate could be varied by either changing the number of hoses or by changing the height of the end of the hoses. During a calibration, the flow rate decreased as the water level lowered in the container. At the end of a calibration run the flow rate was approximately 70 percent of its initial value. The rain rate calibrations were based upon average values (total water/time), as shown in Table 2.

Some of the calibration data obtained from the Weather Measure gage were quite variable. It was not resolved whether the large difference obtained on 13 March was due to the instrument or whether it was a result of the calibration procedure. It is also interesting to note that, with only one exception, all the individual calibrations indicated that the gages underestimated the water amount. A plot of instrument error vs rain rate (Figure 6) indicated that the higher the rain rate, the greater the instrument underestimated the precipitation amount. The same effect was also noted by Middleton;² the magnitude of the underestimation was consistent.

2. Middleton, W. E. K., and Spilhaus, A. F. (1953) Meteorological Instruments, 3rd rev. ed., University of Toronto Press, Toronto, Canada.

Table 2. Calibration of Tipping Bucket Precipitation Gages (1981)

INSTRUMENT	DATE	METHOD	AMOUNT WATER (ml)	TOTAL POUR TIME (MIN)	AMOUNT WATER		AMOUNT CALCULATED (IN)	RAIN RATE		PERCENT ERROR
					MEASURED (IN)	WATER		MEASURED (IN/HR)	CALCULATED (IN/HR)	
WEATHER MEASURE (0.01 in)	06 Feb	hand pour	700	19	0.81	0.88				
	27 Feb	hand pour	1000	19	1.00	1.25				
	13 Mar	1 siphon	1500	119	1.49	1.88		0.75	0.95	-21
	13 Mar	3 siphon	2000	49	1.60	2.51		1.96	3.07	-36
	21 Apr	1 siphon	1000	71	1.28	1.25		1.06	1.08	-1.9
BELFORT (0.01 in)	21 Apr	3 siphon	1500	40	1.73	1.88		2.6	2.8	-7
	06 Feb	hand pour	300	6	0.15	0.16				
	27 Feb	hand pour	1000	13	0.50	0.54				
	13 Mar	1 siphon	1500	111	0.78	0.81		0.42	0.44	-4.5
	13 Mar	3 siphon	2000	29	1.06	1.08		2.2	2.2	0
BELFORT (0.005 in)	21 Apr	1 siphon	1000	64	0.53	0.54		0.50	0.51	-2
	21 Apr	3 siphon	2000	48	1.06	1.08		1.33	1.35	-1.5
	07 May	6 siphon	2000	20	1.06	1.08		3.06	3.24	-5.6
	06 Feb	hand pour	300	7	0.150	0.16				
	27 Feb	hand pour	1000	19	0.495	0.54				
BELFORT (0.005 in)	13 Mar	1 siphon	1500	106	0.795	0.81		0.45	0.46	-2.2
	13 Mar	3 siphon	2000	61	1.075	1.08		1.06	1.06	0
	21 Apr	1 siphon	1000	75	0.545	0.54		0.436	0.432	+0.9
	21 Apr	3 siphon	1500	36	0.790	0.81		1.32	1.35	-2.2

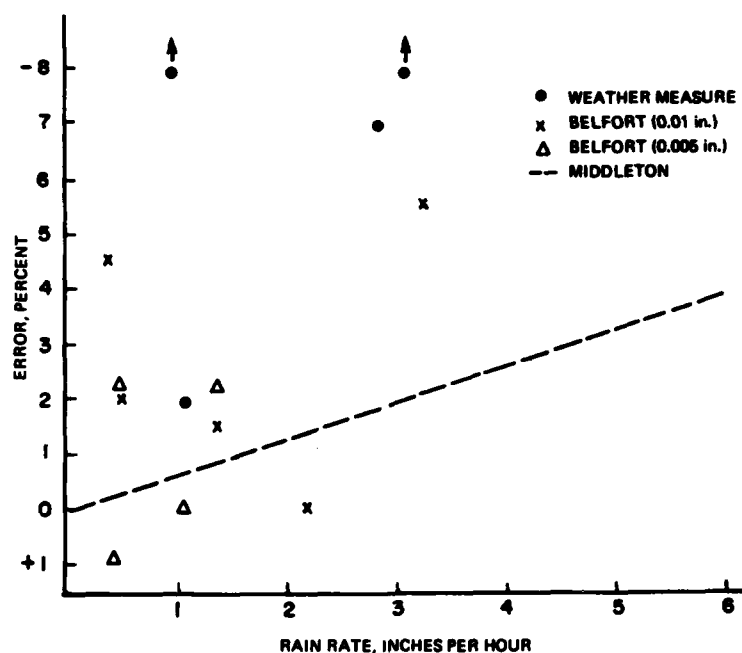


Figure 6. Rate Error of Tipping Bucket Precipitation Gages

3.2 Testing

The gages were field tested from 2 February through 4 April 1981. No failures were experienced by any of the gages. Except for routine cleaning, the gages did not require any maintenance. The test results from all the gages in the 16 precipitation cases which occurred during the test period are presented in Table 3. In two cases, the precipitation was in the form of snow. In six cases the precipitation was so light that no amounts were indicated by the recording gages. The precipitation amounts measured by the other gages during these six cases, were not included in the totals. The results showed that the operational consistency of all the gages was excellent, with the exception of the 0.005 in tipping bucket gage. Excluding this gage, the mean precipitation amount was 7.17 in. (182 mm), with a maximum deviation of 3 percent. The 0.005 in tipping bucket gage indicated a total precipitation amount in this period of 5.64 in. (143 mm), 20 percent less than the mean of the other gages. It was not determined why this gage responded consistently with the other gages to the water amounts in the calibration tests and yet differs from them in responding to precipitation in the field tests. In querying other investigators who have made use of WTF precipitation data in the past, it was learned that this underestimation by the 0.005 in tipping bucket gage had been suspected. Use of this gage at the test site has been suspended until the problem is resolved.

Table 3. Precipitation Experiment Results, AFGL/WTF, Otis AFB, Massachusetts,
2 February Through 5 April 1981

DATE	DURATION (HOURS)	MINIMUM TEMPERATURE (°C)	TYPE OF PRECIPITATION R(RAIN) S(SNOW)	AMOUNT (IN)		AMOUNT (IN)		AMOUNT (IN)		AMOUNT (IN)	
				BELFORT 0.005	BELFORT 0.01	WEATHER MEASURE	BELFORT WEIGHING	RECORDER #1	RECORDER #2	RECORDER #1	RECORDER #2
02 Feb	6	4	R	0.32	0.41	0.41	0.393	0.38	0.40	0.38	0.40
06 Feb	2		S	0.05	0.06	0.06	0.032	0.05	0.05	0.05	0.05
08 Feb	7	2	R	0.875	1.04	1.08	1.113	1.06	1.03	1.06	1.03
17 Feb	-	4	R	0.01	0.01		0.004	-	-	-	-
20 Feb	24	7	R	0.85	1.04	1.07	1.062	1.06	1.06	1.06	1.06
24 Feb	18	6	R	1.125	1.16	1.18	1.181	1.16	1.14	1.16	1.14
26 Feb	13	2	R	0.16	0.23	0.24	0.242	0.25	0.24	0.25	0.24
28 Feb	2	2	R	0.02	0.03	0.01	-	-	-	-	-
06 Mar	24	0	R	0.15	0.36	0.37	0.437	0.42	0.39	0.42	0.39
16 Mar	-	-1	R	0.01	0.03	0.03	0.036	-	-	-	-
21 Mar	-	-1	S	0.005	0.02	0.02	0.014	-	-	-	-
25 Mar	-	4	R	0.04	0.07	0.07	0.061	-	-	-	-
27 Mar	2	5	R	0.09	0.13	0.16	0.123	-	-	-	-
30 Mar	8	10	R	0.235	0.37	0.41	0.332	0.37	0.36	0.37	0.36
02 Apr	6	8	R	1.085	1.24	1.34	1.251	1.26	1.23	1.26	1.23
05 Apr	12	10	R	0.79	1.14	1.24	1.147	1.15	1.15	1.15	1.15
				5.64	7.05	7.40	7.19	7.16	7.05	7.16	7.05

The evaluation results showed both the 0.01 in. Belfort gage and the Weather Measure gage to be suitable candidate precipitation sensors for ATMOS. The Belfort gage performed well and provided consistent and accurate data. The Weather Measure gage, overall, performed well, however, its calibration was more variable and its deviation from the mean precipitation amount was slightly larger than the other gages (excluding the 0.005 in. tipping bucket gage).

4. VISIBILITY

In general, single-ended visibility meters such as lidars and scatter measuring visibility meters, have an advantage over transmissometers for use as tactical visibility meters (TVM) because they are usually easier to transport and install. Lidars were not considered for present application since they were still considered in the experimental stage. In the previous assessment,¹ a number of point visibility meters were described. Though most of these visibility meters have positive aspects, none can adequately satisfy the requirements of a TVM. The most suitable of these, the EG&G Model 207 Forward Scatter Meter (FSM), has been shown to satisfy most of the functional requirements for a tactical visibility meter. However, its size and configuration made it unsuitable for tactical bare-base operations.

AFGL undertook the development of a prototype TVM with Wright and Wright, Inc., Oak Bluffs, Massachusetts. The design goals of the prototype were to:

- (1) Maintain all the positive features of the FSM,
- (2) Improve its transportability and handling,
- (3) Decrease weight,
- (4) Expand measurement range,
- (5) Upgrade electronics, in particular, to improve the reliability of the lamp power supply,
- (6) Improve chopper motor performance,
- (7) Reduce background interference, and,
- (8) Provide covert operations capability.

4.1 Prototype Tactical Visibility Meter

The prototype TVM fabricated by Wright and Wright, Inc. is shown in Figure 7. The meter underwent demonstration testing at the contractor's plant with the following results:

- (1) The measurement configuration of the TVM was similar to the FSM. Such features as the range of measurement scattering angles and the large sampling volume have been retained in the new instrument.

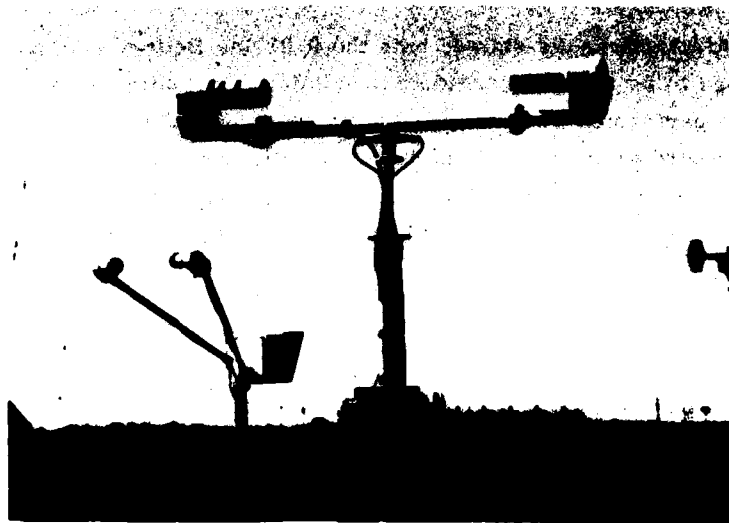


Figure 7. Prototype Forward Scatter Measuring Tactical Visibility Meter (foreground) and EG&G Model 207 FSM (rear)

(2) The configuration of the TVM was more compact, and it was much easier to transport and handle. To demonstrate its ease of handling during installation, the meter was disassembled into its four component parts, reassembled and was ready to operate in 11 minutes. The meter was recalibrated after the procedure. Its calibration changed less than 0.7 percent. The design requirement was for a change of less than 1 percent.

(3) The weight of the TVM was 27.8 Kg, 20 percent less than the design goal.

(4) The meter was designed to have sufficient sensitivity to determine a range of extinction coefficients of $4.9 \times 10^{-2} \text{ m}^{-1}$ to $1.13 \times 10^{-4} \text{ m}^{-1}$. In fog, the TVM's measurement range was verified to $1.3 \times 10^{-2} \text{ m}^{-1}$.

(5) The entire lamp circuit was modified. The new lamp has an estimated life of 15,200 hours (1-3/4 years). Operationally, the routine would be to replace the lamp every six months or whenever the calibrator would indicate the lamp output has begun to deteriorate. A new mount has been provided to facilitate lamp replacement and alignment. The lamp power supply has improved operating characteristics which hold over a greater temperature range than the FSM lamp power supply. The size and weight of the supply were significantly less than the FSM lamp power supply. The size and weight of the supply were significantly less than FSM supply. No separate lamp regulator was required in the new design. In addition to the lamp power supply, the electronics package consisted of a preamplifier, amplifier, synchronous demodulator and a digital voltmeter. The new simplified design used

upgraded state-of-the-art components. The control box containing the electronics can be remotely located up to 30 m from the projector/receiver assembly.

(6) The chopper motor was replaced with a modified motor that had an improved temperature performance capability. In addition, the motor mount was modified to provide a more effective thermal path for conducting heat away from the motor. Both changes are expected to significantly increase the chopper motor's life.

(7) The new meter was not susceptible to vibration induced noise because of its compact configuration. Background interference from random noise sources such as objects scintillating in the instrument's field-of-view on bright days, a problem with the FSM, has been reduced in the TVM by using a higher modulation frequency of 500 Hz. The contractor tested a number of chopper wheels with coded patterns to see if a coded modulation would further reduce the effect of background interference. No reduction in background interference was observed when these coded chopper wheels were used.

(8) For covert operation, an infrared pass filter was inserted internally in the projector's light path. It did not eliminate the visible portion of the light completely. At night, the light was observed to be visible as a dull red glow at 30 m.

4.2 Field Testing

The prototype TVM was field tested at the AFGL Weather Test Facility, Otis AFB, Massachusetts, where it was collocated with a number of visibility meters for comparison purposes. The meters included an EG&G model 207 FSM, a standard 152 m baseline transmissometer, and an experimental side-looking scatter measuring visibility meter. Examples of the comparative test data obtained in a variable fog case are shown in Figures 8, 9 and 10. The time sequence of extinction coefficients (Figure 8) showed that the TVM's output correlated very well with the other meters. Also, the data plots of Figures 9 and 10 indicated that the TVM has an excellent one to one relationship to the FSM and the transmissometer. Data points for extinctions less than $3 \times 10^{-1} \text{ m}^{-1}$ were not included in the plot of Figure 10 because the transmissometer's output was truncated at this extinction level by dirt on its window.

4.3 Preproduction Tactical Visibility Meter

Testing of the prototype TVM demonstrated that it is capable of meeting its design goals and resulted in the tasking of Wright and Wright, Inc. to design a cost-effective preproduction version of the prototype meter. A demonstration model of the preproduction meter, called the "FOG 15," was installed at the AFGL/WTF for design evaluation testing (see Figure 11). Preliminary test results obtained by a comparison of the FOG 15 with a number of the other visibility meters

located at the WTF are shown in Figures 12 through 17. The other sensors were the 91.4 m baseline transmissometer and two EG&G Model 207 FSM's. The results indicated that while the FOG 15 correlated well with the other meters, its calibration was noticeably different. These aspects of the meter's performance, as well as its overall operational capabilities, will be examined further as testing continues.

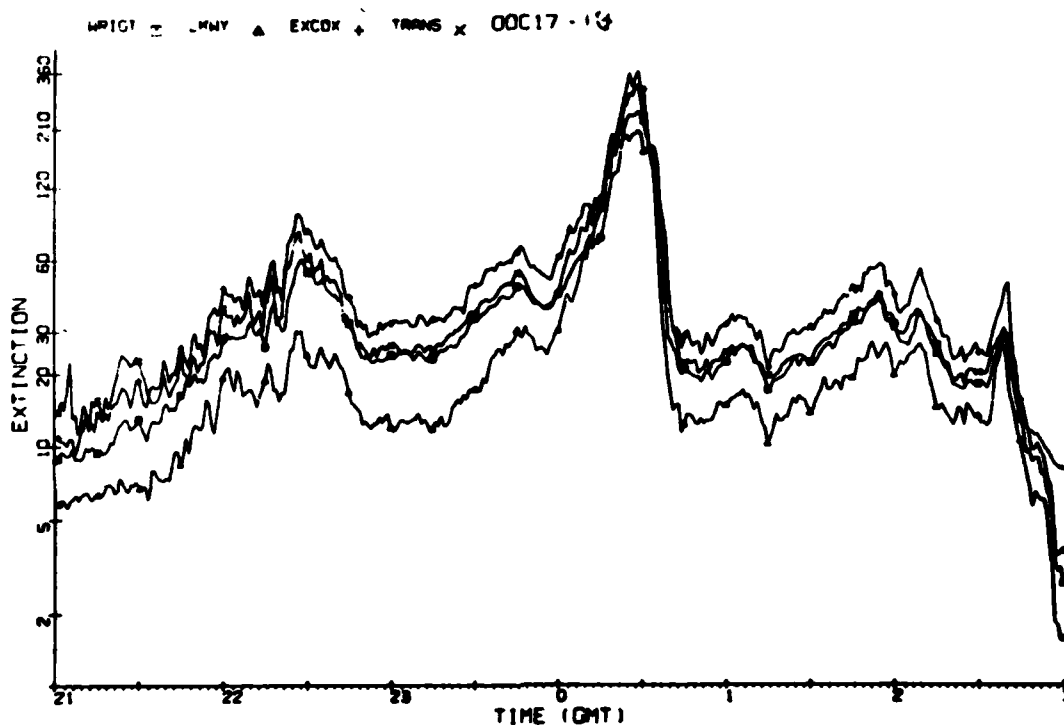


Figure 8. Time Sequence of Prototype TVM (WRIGHT), Experimental Scatter Meter (LKWY), FSM (EXCO X) and 152 m Baseline Transmissometer (TRANS), AFGL Weather Test Facility, Otis AFB, Massachusetts

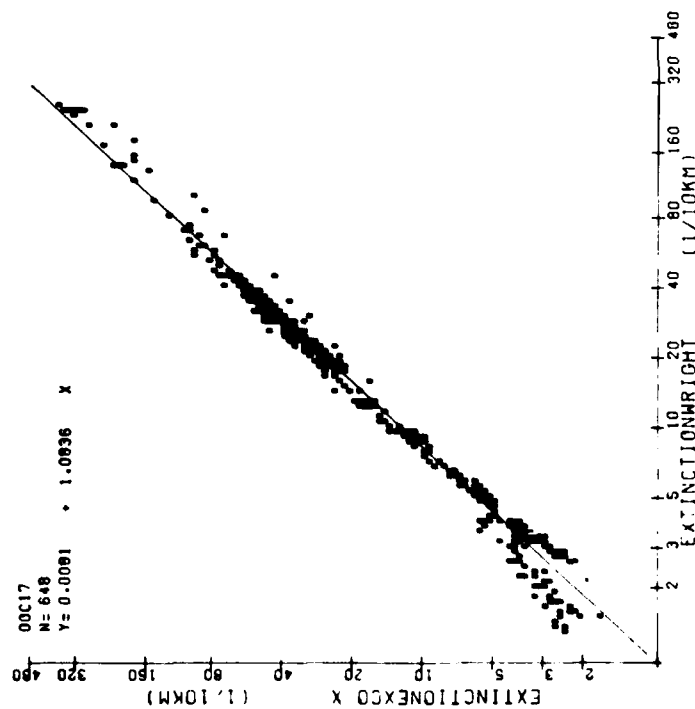


Figure 9. Comparison of Prototype TVM (WRIGHT) and FSM (EXCO X) Measurements

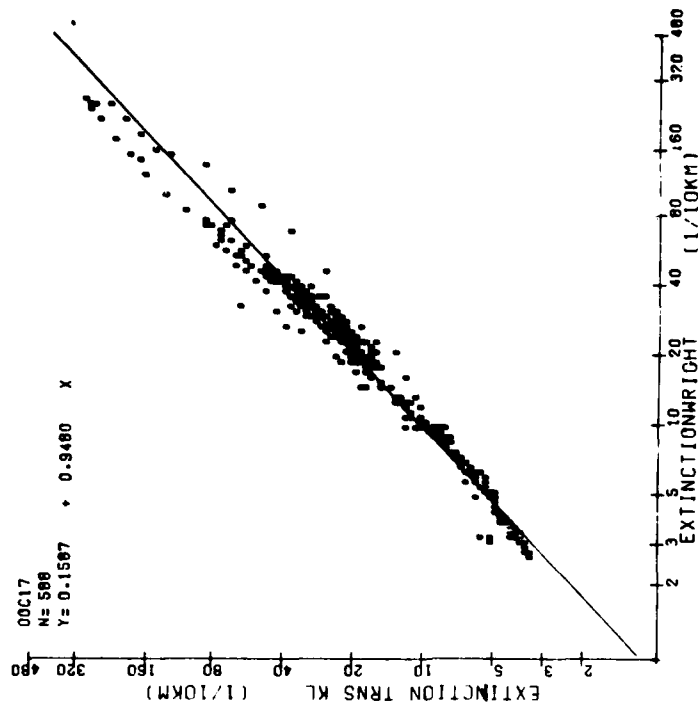


Figure 10. Comparison of Prototype TVM (WRIGHT) and 152 m Baseline Transmissometer (TRNS KL) Measurements

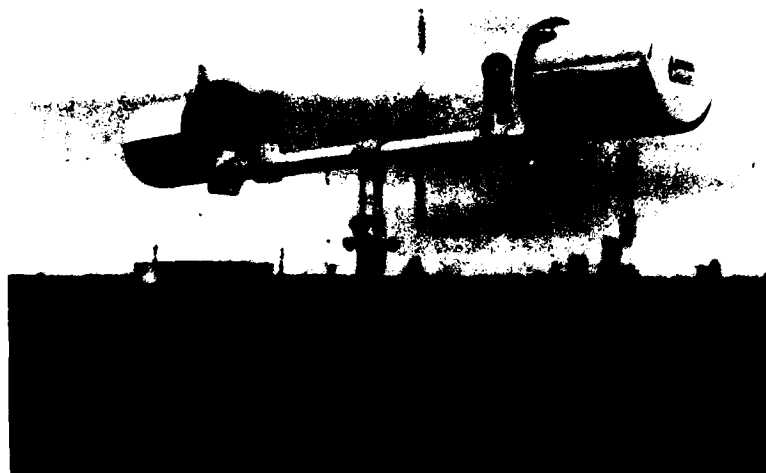


Figure 11. Engineering Model of Tactical Visibility Meter

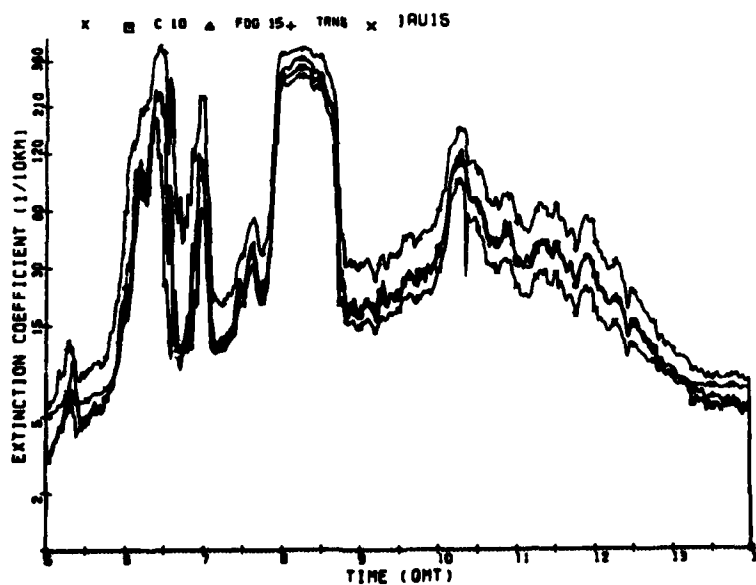


Figure 12. Time Sequence of Engineering Model TVM (FOG 15), Two FSM's (X and C 10) and 92 m Baseline Transmissometer (TRNS), AFGL Weather Test Facility, Otis AFB, Massachusetts

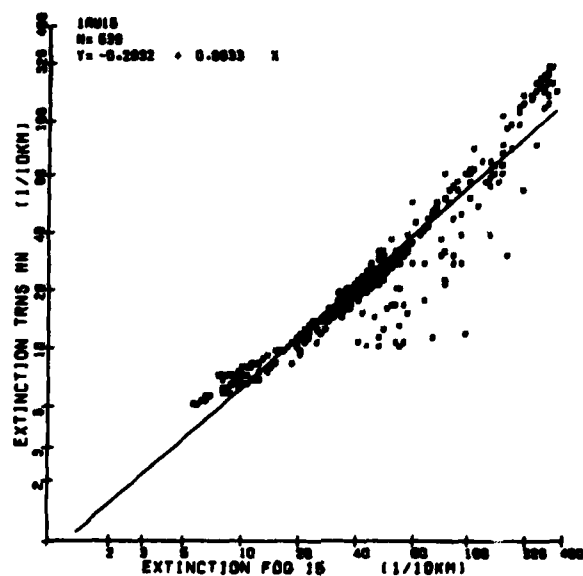


Figure 13. Comparison of Engineering Model TVM (FOG 15) and 92 m Baseline Transmissometer (TRNS MN) Measurements

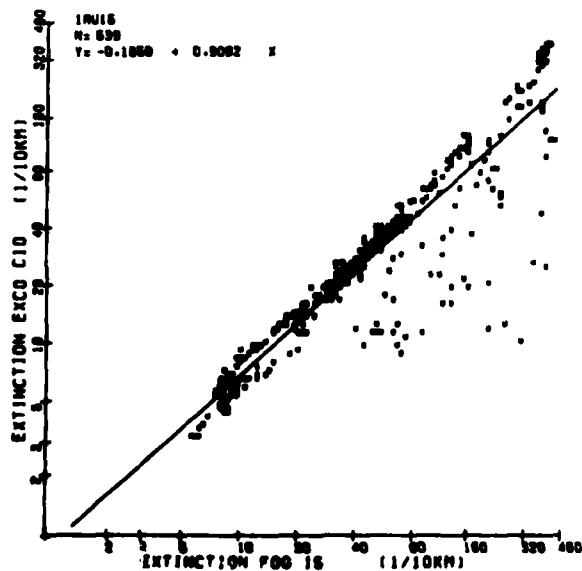


Figure 14. Comparison of Engineering Model TVM (FOG 15) and FSM (C 10) Measurements

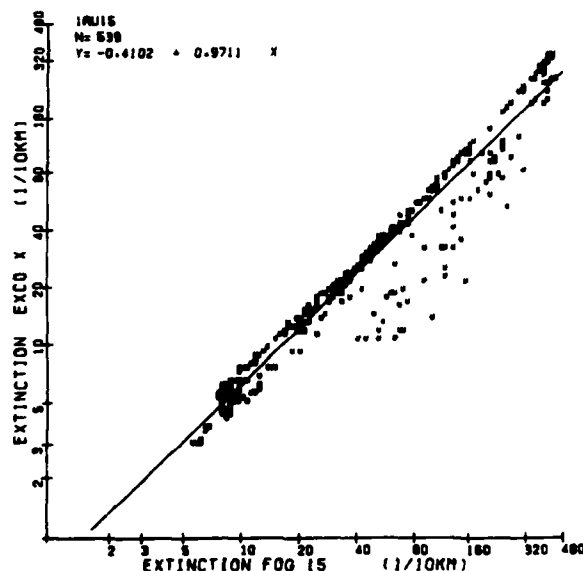


Figure 15. Comparison of Engineering Model TVM (FOG 15) and FSM (X) Measurements

5. CLOUD HEIGHT

The status of the various cloud height sensor developments has not changed significantly since the last report.¹ FAA's efforts with Hughes Laser Systems Division and Sanders Associates, Inc. for an eyesafe laser ceilometer, ended without producing an operational system.

In response to a request from AWS, a AN/GVS-5 laser rangefinder was tested at AFGL/WTF to: (1) determine whether the rangefinder meets AWS's requirements for a tactical forward area cloud height measuring set and, (2) evaluate its potential for application to tactical bare-base operations.

5.1 AN/GVS-5 Laser Rangefinder

A detailed description of the AN/GVS-5, a compact, hand-held Q-switched neodymium YAG laser rangefinder, has been given by Woodward.³ It was designed to determine the range of solid targets between 220 and 9990 m away. The range of a target is determined by measuring the time it takes the laser pulse to travel to the target, be reflected and return.

3. Woodward, J. A. (1977) The AN/GVS-5 hand-held laser rangefinder, RCA Engineer, 22(No. 6):48.

A laser hazard evaluation was made prior to operating the AN/GVS-5 at AFGL/WTF, Otis AFB, Massachusetts. The evaluation showed that the laser presented no corneal or skin hazard; however, it can cause retinal damage. Its safe eye exposure distance (SEED) for the unaided eye was 1170 m. If 7 x 50 mm binoculars were used the SEED extended to 8300 m. In order to have a completely eyesafe laser beam in the airspace beyond the control of Otis AFB, that is, at altitudes above 915 m, it was necessary to insert an optical filter with a minimum optical density (O.D.) of 1.9 at the exit aperture of the laser. The optical density of the filter obtained for the test was 2.0. Test results were obtained with and without the filter in place.

5.2 Testing

Comparative measurements of cloud height were obtained using the AN/GVS-5 and a modified AN/GMQ-13, Rotating Beam Cloud Height Set (RBC). The baseline of the RBC was 122 m. The AN/GVS-5 was operated at a location 300 m from the RBC.

The testing took place over a six month period and included measurements in rain, snow, fog, and "good weather." The results were as follows:

(1) "Good Weather": The lowest cloud height obtained with the rangefinder was 180 m (590 ft), its minimum range. The maximum cloud height measured with the 2.0 O.D. filter in place was 1160 m (3805 ft). The maximum range obtained without the filter in place was 2270 m (7450 ft). The AN/GVS-5 cloud height indications agreed well with the RBC returns.

Only, limited success was obtained in trying to lower the rangefinder's effective cloud height minimum range by firing at various elevation angles and converting this slant range measurement to an equivalent vertical cloud height. The results were sporadic at an elevation angle of 45°. Since the effect, at this angle, would be equivalent to lowering the minimum range by only 60 m, the method was not recommended.

The AN/GVS-5 had a variable minimum range feature which permitted one to range beyond the first target to a second, and then to a third. This mode of operation was tried on solid targets and worked well. However, the rangefinder was unable to detect any cloud layers beyond the first layer when the RBC was indicating multiple returns.

The AN/GVS-5 did not provide consistent measurements when diffuse, overcast sky conditions existed. The RBC continued to indicate a weak return from the same overcast layer.

(2) Rain: Cloud height measurements were obtained with the rangefinder in light rain conditions where the cloud bases ranged from 200 to 1250 m. These

measurements generally agreed with the RBC indications, however, moderate to heavy rain severely attenuated the laser signal and no cloud returns were obtained in these conditions. Moreover, there was evidence that virga adversely affected the laser signal. On one occasion, returns were being obtained from a cloud layer, but as virga moved over the site, the rangefinder stopped indicating returns.

(3) Snow: During the test period, the RBC detected a cloud layer in falling snow on a number of occasions. Only once did the rangefinder indicate a cloud height (at 800 m). The rangefinder was operated without a filter on this occasion.

(4) Fog: Several cloud height measurements were obtained with the RBC in fog; however, no corresponding cloud returns were detected with the rangefinder.

5.3 Summary

The AN/GVS-5 performed well as a cloud height measuring device in "good weather" conditions, and, it was superior to any tactical cloud height instrument in AWS's inventory. However, a number of improvements were shown to be necessary in its operational capabilities before it can be considered a completely suitable candidate for use in ATMOS. These improvements include:

- (1) Eyesafe operation,
- (2) Better performance in rain, snow and fog,
- (3) Lowering of its minimum range from 200 m to 30 m, and
- (4) An automated capability.

6. TEMPERATURE AND DEW POINT

The AN/TMQ-20, Tactical Temperature/Dew Point Measuring Set has a Peltier-cooled optical dew point hygrometer and uses a platinum resistance thermometer to measure free-air temperature. Our evaluation¹ showed that it was the only set in the AWS inventory that could satisfy the functional temperature and dew-point requirements. Since it is the standard tactical temperature/dew-point sensors, the development of a translator for automated operation appeared as a worthy objective.

A block diagram of the temperature portion of the translator, also designed and built by Ertec, Inc., is shown in Figure 16. An identical circuit was used to condition the dew-point temperature measurement. It has three outputs for both the free-air and dew-point temperatures:

- (1) A ten-bit databus processor output for temperature information over the range of -80°F to $+130^{\circ}\text{F}$,
- (2) An analog output for recording purposes, and
- (3) A three and one-half digit LED display.

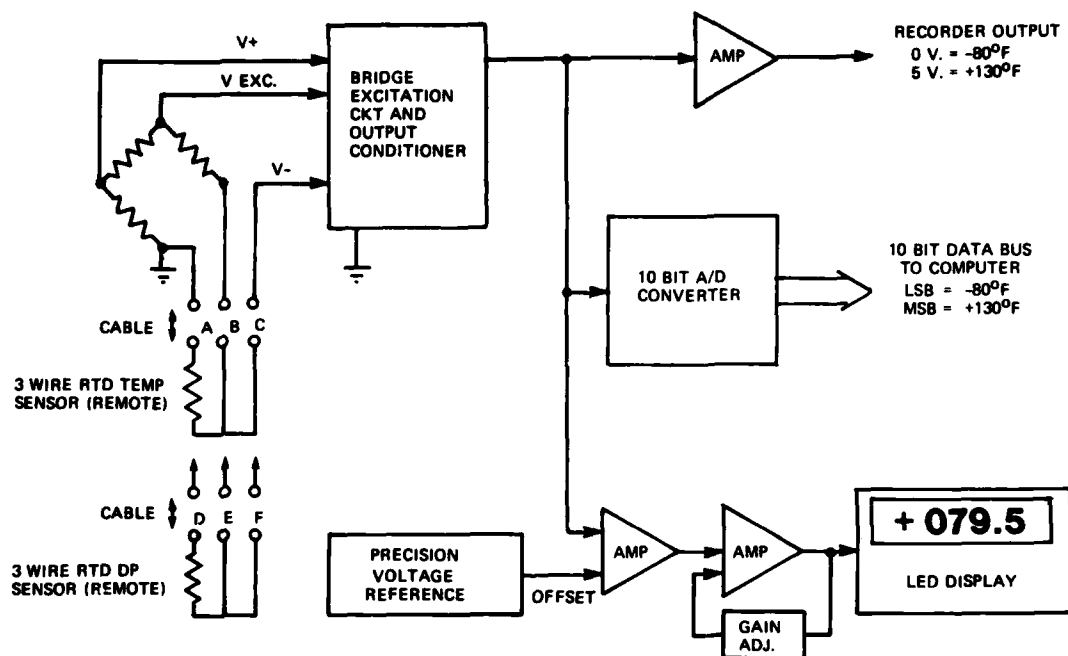


Figure 16. Block Diagram of Translator for Automating Operation of AN/TMQ-20, Tactical Temperature/Dew Point Measuring Set

The translator (Figure 17) has been delivered and bench checked. No field tests have been conducted since the effort in this area had been discontinued.

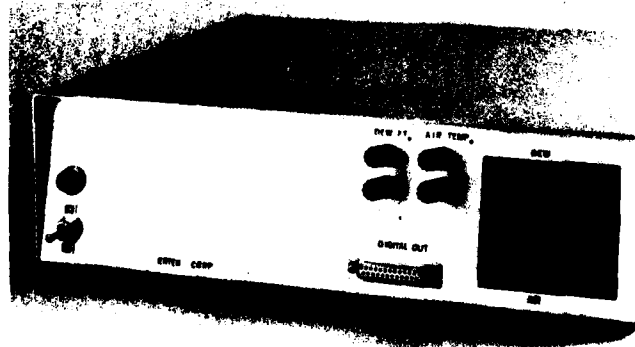


Figure 17. Engineering Model of AN/TMQ-20 Translator

7. CONCLUSIONS

A major portion of the development of an Automated Tactical Meteorological Observing System has been completed. Commercially available sensors suitable for use in ATMOS have been identified in all the required measurement categories with the exception of visibility and cloud height. Also, translators which automate the operation of two of AWS's sensors, the AN/TMQ-15 Tactical Wind Set and the AN/TMQ-20, Tactical Temperature/Dew-Point Measuring Set, have been built and demonstrated. To provide a suitable visibility sensor, AFGL has undertaken the development of a forward scatter measuring tactical visibility meter. The development has proceeded through demonstration of the prototype model and recently an engineering model was delivered to AFGL for field testing. A laser rangefinder, AN/GVS-5, was tested as a cloud height sensor. The test proved again that laser devices can accurately measure cloud height; however, the AN/GVS-5 is not eyesafe, and the prospects of having a suitable eyesafe cloud height sensor in the near future is poor.

Future plans for development of the tactical weather station have been curtailed due to manpower changes in the Meteorology Division. Only the development of the tactical visibility meter will be completed.

Appendix A

Manufacturer's Specifications of Candidate Precipitation Gages

BELFORT MODEL NO. 5-405 HA TIPPING BUCKET PRECIPITATION GAGE

ACCURACY:	1% of rainfall rate of 1 in. /hr 4% of rainfall rate of 3 in. /hr 6% of rainfall rate of 6 in. /hr
ORIFICE:	30.5 cm
SENSITIVITY:	0.01 in.
MIN. OPERATING TEMPERATURE:	-20°F (-29°C)
MAX. SNOWFALL CAPABILITY:	3 in. /hr at -20°F
SIZE:	65 cm diameter × 96 cm high
WEIGHT:	Net - 16.8 kg, gross -25 kg
POWER:	115 Vac, 325 W

WEATHER MEASURE 0.01-in TIPPING BUCKET PRECIPITATION GAGE

ACCURACY:	0.5% of rainfall rate of 0.5 in. /hr
ORIFICE:	20 cm
SENSITIVITY:	0.01 in
HEAT CONTROL:	Thermostat adjustment, 0° to 35°C
SIZE:	24 cm diameter × 46 cm high
WEIGHT:	9.3 kg
POWER:	110 Vac, 50/50 Hz, 500 W